National Aeronautics and Space Administration

Structural Materials

Titanium- and Zirconium-Based Wires

NASA Marshall Space Flight Center

Wire is a mainstay of spacecraft components such as umbilical tethers, and it may well enable novel space transportation systems such as space elevators, solar sails, and tether propulsion. Exploration spacecraft will need wires that are light, strong, and serve multiple purposes. Wire and other materials will be exposed to the harsh thermal, radiation, and vacuum environments of space for longer periods and may even need to operate near a nuclear fuel source. Titanium and zirconium materials are commonly used in aerospace applications and appropriate alloys/microstructures may provide candidate wires due to their strength-weight ratio, corrosion resistance, and wide range of temperature applicability.

An earlier study by this principal investigator resulted in the first known fabrication and evaluation of pearlitic-type titanium- and zirconium-based alloy compositions for potential wire applications. The research began with the postulation that a unique group of titanium- and zirconium-based alloy wires could be fabricated based on the process used to make high-strength cords for tire manufacturing. In this process, the iron-carbon alloy isothermally transforms via a solid-state eutectoid reaction to form two new compositions, or phases. The spacing between the two phases is often fine enough to break up light and give the material a pearl-like appearance, hence the name pearlite. Interactions between the phases contribute to the strength, which is further increased by drawing the wire to a thinner diameter. Examination of titanium and zirconium phase diagrams showed when these base metals were properly alloyed and heat treated, they exhibited a pearlitic-like microstructure, which would be useful for producing novel composite wires.

Task Description

This Advanced Materials for Exploration (AME) research builds on the prior study. Investigators will fabricate wires made of titanium and zirconium alloys and test the wires to see if they have the properties required for operation in the harsh space environment. Tasks include

1. Completing studies of relevant scientific and technical data
2. Applying previous knowledge to facilitate fabrication processes
3. Fabricating and heat treating wires
4. Characterizing wire microstructures
5. Testing, modeling, and evaluating wire mechanical properties.

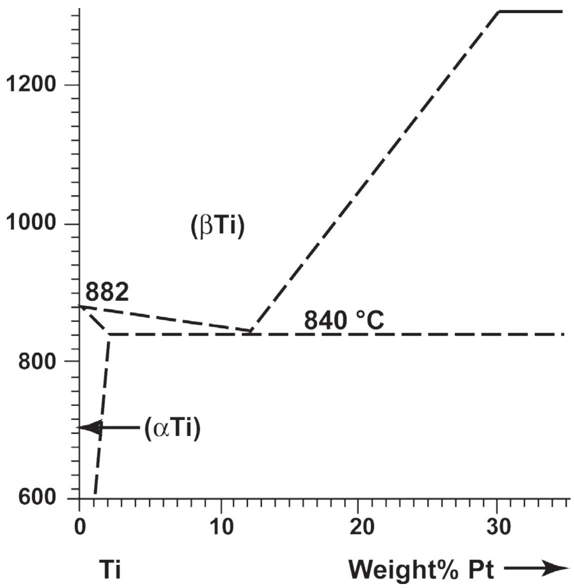
This 10-month effort was initiated and will be completed in FY06.

Anticipated Results

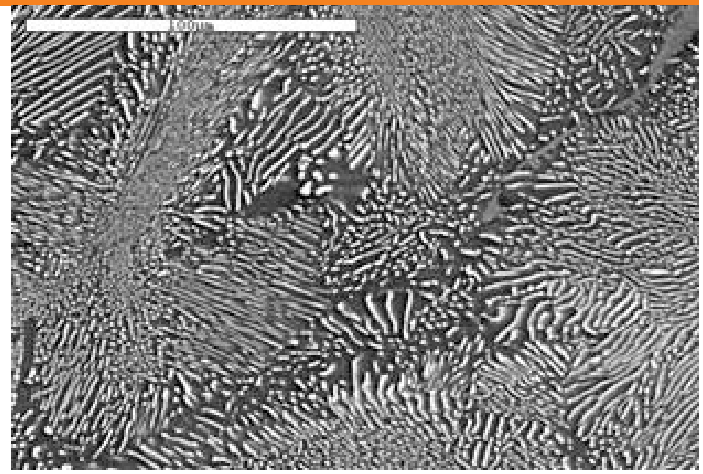
In the prior study, the following series of alloys, among others, were cast, heat-treated, and slowly cooled through the appropriate eutectoid-type reaction to yield a pearlitic microstructure: titanium-silver, titanium-platinum, titanium-palladium, zirconium-silver, zirconium-platinum, and zirconium-palladium. Under the current study, the alloy

advanced materials for exploration

TITANIUM- AND ZIRCONIUM-BASED WIRES



This partial titanium-platinum phase diagram shows a eutectoid reaction at Ti-12wt.%Pt. The principal investigator has produced several pearlitic-type microstructures based on titanium and zirconium alloys exhibiting eutectoid reactions.



This micrograph shows the Ti-12wt.%Pt microstructure after processing at ~1373 K for ~24 hours and then cooling at 0.1 K/s. A lamellar eutectoid structure consisting of alternate sheets of Ti and Ti3Pt, an intermetallic compound, is seen.

compositions will be fine-tuned based on previous results, cast samples will be vacuum heat treated, and samples will be prepared for mechanical testing. Microstructural characteristics/development of the alloys will be examined and recorded throughout the fabrication and testing steps. The resultant mechanical properties of each alloy will be compared with established commercial products, and steps will also be taken to determine the material's potential use in spacecraft components needed for deep space exploration missions.

The wires will be fully fabricated, tested, and evaluated within Marshall Space Flight Center (MSFC) laboratories, including alloy development, heat treatment, and mechanical deformation (rolling and drawing). Diagnostic facilities include a complete metallographic preparation laboratory, diagnostic X-ray equipment, optical microscopes, microprobes, and electron microscopes.

Potential Future Activities

The next steps are to test these novel wire samples in a simulated space environment (vacuum, radiation exposure, extreme temperatures) and to use them in prototype components for structural and propulsion elements. MSFC has the resident materials experts and facilities to produce the wires, test them in simulated space environments, and evaluate their performance.

Capability Readiness Level (CRL)

This AME task will fabricate and test titanium- and zirconium-based wires, among others, in the laboratory (CRL 4). Subsequent testing under simulated space environment conditions would elevate this technology to CRL 7 and provide materials selection criteria for designers of spacecraft structural components and propulsion systems. Development of these materials will contribute to the efficiency and reliability of future spacecraft.

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